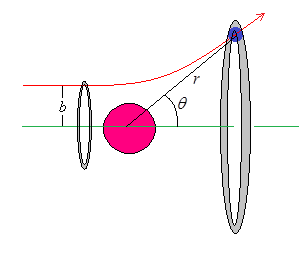
**Inelastic Scattering**

Now let’s consider the possibility that there is some internal structure to the scattering target, which can siphon energy, as well as momentum, from the scatterer.



I guess we’ll start with box normalized plane-wave states, |kbox> = ei**k**·**r**/√V, like we did at the end of the previous file. We can still say,



Moving to the energy-dependent cross section we can say,



Now from TDPT, for a two particle interaction where say we have the scatterer in state |k>box and target molecule in state |λ> (these occupy separate Hilbert Spaces), which then transitions to states |k´>box and |λ´> respectively, via interaction V:



It’s common, also, to put the V matrix element in terms of delta normalized states, rather than box states. Switching to these states, then we’d have:



Also change variables to ω = Ek´­ - Ek.



Finally we average over all initial and final target states, where Pλλ´ is the probability of those initial and final states. Usually the probabilities are taken to be thermal probabilities (see stat mech). Actually, it seems we typically presume that having chosen the initial target state |λ>, the transitioned state |λ´> is fixed, once |k´> has been specified. So there is only an average over initial target states, Pλ.



**Neutron Scattering off of Crystal Lattice**

In this context, we’re usually talking about neutron scattering, which, being uncharged, is typically off of nuclear potentials. Though the impact of the neutrons will excite the nucleus to higher energy levels, I’m assuming these will be the kinetic energy levels representing the motion of the nuclei’s center of mass, not internal excitations that would induce radiation emission, etc.. In any event, we may accurately represent the interaction via a delta function, since the range of the nuclear potential is only about the size of the nucleus. Let Ξ have units of energy-volume and represent the strength of each nuclei’s potential. Then the potential of the entire crystal would be:



where **r**i = **R**i + **x**i, and **R**i is the equilibrium position of the crystalline nucleus (a scalar), and **x**i (an operator). ri is an operator in the HS of the crystal Hamiltonian. Let’s get the matrix element:



Where in the last we recognize,



as the Fourier transform of the crystal density. So then we can write:



And then,



Plugging this in we now have:



Now let’s put the delta function in Fourier representation:



Can put this in terms of Heisenberg picture,



We can remove the sum over λ, now,



Last we can recognize the first three operators as the Heisenberg representation of the time-developed operator.



So,



where H is the Hamiltonian. I guess not last. Let’s define **q** = **k**´-**k**. Then,



As we’ll get to later, the thing in brackets is called the (well N× the) Structure factor (see identical particles/correlations file),



so then we have:



Recognizing the Fourier transform of course, we can say at last,



We’ll use this formula when discussing quantum fluids…